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Energy Procedia 56 (2014) 505 – 509

Energy Procedia

11th Eco-Energy and Materials Science and Engineering (11th EMSES)

Applied MATPOWER for Power System Optimization Research

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Abstract

This paper provides the applied MATPOWER techniques for optimization solving in power system research. MATPOWER has been powerful developed for power flow and optimal power flow solving. These two mains of MATPOWER are importance for electrical energy management in terms of loss reduction in power systems and system performance improvement. In power flow solving of MATPOWER process can be applied for conveniently solving in heuristic optimizations. Example of optimal capacitor placement is illustrated for practical guiding.

Peer-review under responsibility of COE of Sustainalble Energy System, Rajamangala University of Technology Thanyaburi (RMUTT)

Keywords:MATPOWER, Power System Optimization, Heuristic Optimization;

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Peer-review under responsibility of COE of Sustainalble Energy System, Rajamangala University of Technology Thanyaburi (RMUTT)
doi:10.1016/j.egypro.2014.07.185

1. Introduction

Power system optimizations become important that make system operator can operate at lower cost. Also, power system securities are included in solving process. MATPOWER [1] is a powerful MATLAB [2] programming package providing for power flow and optimal power flow solving. However power system optimization problems are more complication and diversity when additional constraints are considered. Thus the heuristic algorithm optimization is required. If we can apply MATPOWER into the new heuristic algorithms, the convenient solving should be occurred.

Several author researches that related with applied MATPOWER in the process of optimal finding have been published. Such in [3], optimal micro grid system and influence in distribution system are studied. Power flow calculation by applied MATPOWER is encounter into objective function evaluation process. In [4], optimal multi-type distributed generators (DGs) placement is solved. Applied MATPOWER is taken into objective function of multi-objective optimization NSGA-II for power system loss calculation. In [5], distribution system including DGs reconfiguration is considered for loss reduction. Power flow analysis by applied MATPOWER is used for finding the system power loss of objective function. Also in [6], the optimal line automatic voltage regulation (AVR) placement and tap setting in distribution has been proposed. Moreover in [7], the hybrid of loss sensitivity factor and particle swarm optimization (PSO) is used to find the optimal DG placement. These all author researches [3-7] use applied MATPOWER in the objective function for finding the system loss and voltage profile.

In this paper the technique of applied MATPOWER into the new optimization technique such as particle swarm optimization (PSO) is contributed. The typical example of optimal capacitor placement is illustrated for practical guiding.

2. MATPOWER

MATPOWER is an open source programming package for power flow analysis and optimal power flow (OPF). It is developed by Power System Engineering Research Center (PSERC). The present volume is V. 1.14. Although MATPOWER requires running on licensing computer language MATLAB, convenient programming development is interesting. The process of MATPOWER comprises of three steps.

Step 1: input file, the power system data such bus data, branch data and generator fuel cost function will be read for next step.

Step 2: the power flow is calculated by Newton-Raphson method (default method).

Step 3: all results display

In step 1, the input data is prepared. There is specified in a set of matrices package as a fields of a MATLAB structure, referred to as “MATPOWER case” structure. This structure is typically defined in a case file; see CASEFORMAT for details on the case file format. This is an example for the 4 buses and two generators (case4gs).

```
function mpc = case4gs
%% MATPOWER Case Format : Version 2
mpc.version = '2';
%%-----  Power Flow Data  -----%%
%% system MVA base
mpc.baseMVA = 100;
%% bus data
mpc.bus = [
    1   3   50  30.99   0   0   1   1   0   230 1   1.1 0.9;
    2   1   170 105.35  0   0   1   1   0   230 1   1.1 0.9;
    3   1   200 123.94  0   0   1   1   0   230 1   1.1 0.9;
    4   2   80  49.58   0   0   1   1   0   230 1   1.1 0.9;
];
%% generator data
mpc.gen = [
    4   318 0   100 -100  1.02 100 1 318 0 0 0 0 0 0 0 0 0 0 0 0;
```

```
    1   0   0  100 -100  1.00 100 1 0   0 0 0 0 0 0 0 0 0 0 0 0;
];
%% branch data
mpc.branch = [
    1   2   0.01008 0.0504  0.1025  250 250 250 0   0   1   -360    360;
    1   3   0.00744 0.0372  0.0775  250 250 250 0   0   1   -360    360;
    2   4   0.00744 0.0372  0.0775  250 250 250 0   0   1   -360    360;
    3   4   0.01272 0.0636  0.1275  250 250 250 0   0   1   -360    360;
];
```

In step 2, the load flow solving is called by main simulation functions, such as runpf or runopf. For example, to run a simple Newton power flow with default options on the 4-bus system defined in case4gs.m, at the MATLAB prompt, type:

```
>> runpf('case4gs');
```

If, on the other hand, you wanted to solve the typically case such as increase its real power demand at bus 4 to 100 MW, then run AC power flow with default options, it could be accomplished as follows:

```
mpc=loadcase('case4gs');    % read the load flow input data
mpc.bus(1,PD)=100;          % increase the real power demand at bus 4 to 100 MW, DP load demand (MW)
runpf(mpc);                 % run AC power flow
```

In step 3, the results of the simulation are pretty-printed to the screen, displaying a system summery, bus data, branch data, for the OPF, binding constraint information. The solution is also stored in a results structure available as an optional return value from the simulation functions. This results structure is a set of the MATPOWR case structure mpc, with additional columns added to some of the existing data fields and additional fields. The following example show how to simple it is, after running a AC load flow on the 4-bus system in case4gs.m, to access the final objective function value, the real power output of generator 2 and the power flow in branch 2 (from bus 1 to bus 3).

```
>>results=runpf('case4gs')                % run load AC load flow and to access the final objective to results
>>gen2_output = results.gen(1,PG)         % the real power generation (MW) of generator at bus 1
>>branch13_flow = results.branch(2, PG);  %  the real power flow (MW) of the branch 2 (from bus 1 to bus 3)
```

MATPOER has many options for selecting among the available solution algorithms controlling the behaviour of the algorithms and determining the details of the pretty-printed. This is controlled by mpoption function. For example, the following code runs a power flow, to turn the verbose option off and rerun with the remaining options unchanged, simply pass the existing options as the first argument to mpoption.

```
>>opt = mpoption('VERBOSE',0, 'OUT_ALL',0); % set option of MATPOWER
>>results=runpf(mpc, opt); % run load flow for mpc (case4gs) with option
```

For more information on MATPOWR's options, see Appendix C in the user manual or type:

```
>> help mpoption
```

3. Power System Optimization and Applied MATPOWER

Normally heuristic optimization techniques require iteration for better solution hit. Each iteration, the new solution will be generated with better objective value. The practical heuristic optimization is shown as following figure.

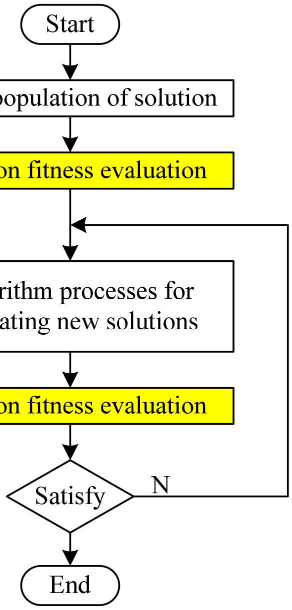

Figure 1. Flowchart of conventional heuristic optimization algorithms

From figure 1, the solution fitness evaluation is one importance since solution fitness making the algorithms decision. Here we will use some partial part in MATPOWER for finding either solution fitness or objective function. Example of objective function of capacitor placement evaluation is shown.

The capacitor placement in 33-bus distribution system is presented in [8]. The objective function is to minimizing the system load voltage deviation (LVD) as following:

$$Min \quad f_1(x,u) = \sum_{k=1}^{n} \left(\frac{V_k^{ref} - V_K}{V_k^{ref}} \right)^2 \tag{1}$$

The variable x is the optimal sizing and location of capacitor to be placed in the system. There are two vectors of search space, sitting and sizing of capacitor. The sitting is varied from bus 2 to 33.

This generated value is from the uniform distribution on interval [a, b] as:

```
sit_Cap = a + (b-a)*x(1); %x(1) is varied between 0 and 1
```

Capacitor size is varied between minimum to maximum as:

```
size_Cap = MVAR_max*x(2); %x(2) is varied between 0 and 1
```

All programming for objective function evaluation is shown as following:

```
function f = evaluate_objective(x)
% x is variable (location and size of Capacitor)
% x(1) is siting
% x(2) is size
% f objective function
%--- place capacitor
Sit_PV=round(2 + 31*x(1));  % location of capacitor (bus 2 to bus 33)
Size_PV=MVAR_max*x(2);      % size of capacitor
data=case33_bus;            % call load flow input data (case 33_bus)
```

```
data.gen(site_PV,Status)=1; % turn on capacitor at bus
data.gen(site_PV,QG)=size_PV; % place capacitor

%--- Run power flow
opt = mpoption('VERBOSE',0, 'OUT_ALL',0);
results = runpf(data, opt);

%---evaluated objective function
%   calculate the load voltage deviation (LVD)
Vref(1:33)=1;
Vref=Vref';
V_bus=mpc.bus(:,VM);
Vdif=Vref-V_bus;
Vdif2=Vdif.*Vdif;
LVD=sum(LVD);
f=LVD;  % objective function
clear x;
return;
```

As above programming, we can apply for several new heuristic algorithms optimization. In some optimization requires multi-objective functions such as voltage profile and power system loss, this applied MATPOWER can also be introduced [4].

The capacitor placement in 33-bus radial distribution system is presented in [8]. The objective function is to minimizing the system load voltage deviation (LVD). Test result show that, the optimal size of capacitor is 9421 KVAR to place at the bus 12. The load voltage deviation improvement is 96.94 percentages that compare to the base case.

4. Online license transfer

A technique of applied MATPOWER into objective function of a heuristic optimization is proposed. Only few correcting in MATPOWER is required. If any problem in power system that require result of power flow calculation, this applied MATPOWER can be coped. Thus, if any researcher needs to study as this condition, this paper might be helped. The whole optimal capacitor placement example programming can be downloaded from [9].

Acknowledgements

Acknowledgements and Reference heading should be left justified, bold, with the first letter capitalized but have no numbers. Text below continues as

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